



Bently assists Sandia in upgrading weapons test centrifuges



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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000. These major facilities perform research and development which is important to U.S. national security. One of Sandia's most important responsibilities is to ensure that the nation's nuclear weapon stockpile meets the highest standards of safety, reliability, security, use control, and military performance.

Sandia also operates a Weapons Evaluation Test Laboratory (WETL) at the U. S. Department of Energy's Pantex Plant near Amarillo, Texas. It is the major facility for assembling and dismantling nuclear weapons, and for performing subsystem testing of new and stockpiled weapon systems for the Sandia Surety Assessment Center.

It is operated by Mason & Hanger - Silas Mason Co. Inc. Bently Nevada recently worked with Sandia to instrument two new centrifuges that will be used by WETL during tests of weapons electronic systems.

WETL uses two 222,400 g·N (50,000 g·lb) centrifuges, designed by Sandia in the late 60s and early 70s, to provide a high onset/decay

rate g environment during system tests (Figures 1 and 2). These centrifuges test nuclear weapons components and subassemblies under conditions of severe acceleration to verify performance, reliability, and safety. The two centrifuges, which have been modernized several times in the past, are the equipment in greatest use at WETL; every sys-

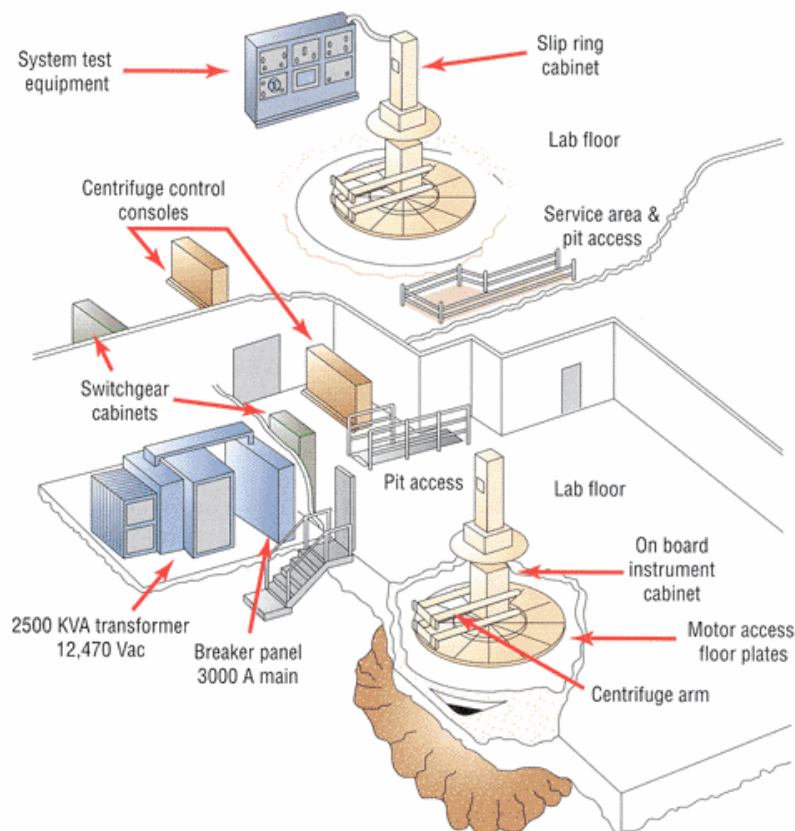


Figure 1. Large centrifuge (2) facilities at Sandia WETL/Pantex.

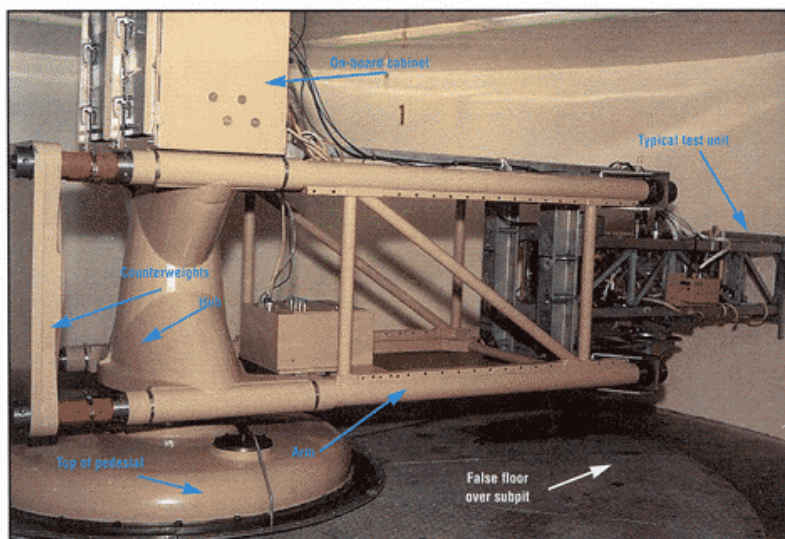


Figure 2. One of two hydraulic-motor-driven centrifuges.

tem component or assembly must operate in a high g field at some point in the test process. The centrifuges provide the g environment that a particular test assembly would be subjected to in actual use; that is, acceleration and deceleration on board a launch vehicle (single or multi-stage), deceleration during reentry to the earth's atmosphere, or deceleration upon release from an aircraft, for example, parachute deployment.

In the present WETL test program, centrifuge g loads range from 1.9 g applied to a 133 N (30 lb) test unit to 140 g applied to a 1557 N (350 lb) assembly. The most severe g onset occurs when a 1423 N (320 lb) test assembly is accelerated to 33 g in one second. This test profile requires maximum torque output from the centrifuge drive system.

The drive systems for each centrifuge are similar; one uses 93 kW (125 hp), the other 112 kW (150 hp) electric motors. Each centrifuge has three drive units, spaced 120 degrees apart. Each drive unit consists of a 1780 rpm electric motor that drives a variable displacement hydraulic pump, which, in turn, drives a constant displacement

hydraulic motor (Figure 3). The hydraulic motors are coupled to the centrifuge spindle bull gear by pinion gears. The two centrifuges have nearly identical control systems.

The control systems were scheduled for an upgrade starting in 1992. A design team was formed to study the operation and performance of the centrifuges, and to gain background information to help them modernize the control systems. Using Bently Nevada proximity probes, accelerometers, and signal conditioning equipment on hand from previous centrifuge projects, the design team instrumented one of the centrifuges for a system performance study. Two proximity probes, mounted 90 degrees apart, observed the upper flange of the centrifuge case, to measure case deflections in the X and Y directions. A Keyphasor® (once-per-turn reference) transducer was installed on the bottom of the flange of the centrifuge

arm to correlate the position of the centrifuge arm with case deflection. The proximity probe and Keyphasor signals were processed by a Bently Nevada Digital Vector Filter 2 (the DVF 2 displays rpm, displacement, and phase angle) for balance condition detection and correction. For data correlation, the signals were displayed in orbit format on an oscilloscope. The turning rate of the centrifuge arm was measured by a dc tachometer mounted on the bottom of the centrifuge spindle. Case and arm vibration data were collected using oscilloscopes, strip chart recorders, the DVF 2, and a spectrum analyzer.

Potential safety problem with existing centrifuges

A known unbalance weight was added to the end of the arm, and case deflections relative to the floor were measured at various turning rates using the DVF 2. Using this data, the moment (or wobble stiffness) of the centrifuge structure was calculated to be approximately 1870 N·m (1380 ft·lb) per arc second. This indicated that the centrifuge structure was sufficiently stiff to be tolerant of relatively large unbalance forces. However, the design team noted that the electric motor and pump assemblies were mounted on the centrifuge pit floor, while the hydraulic motors were mounted on the centrifuge case. Between the

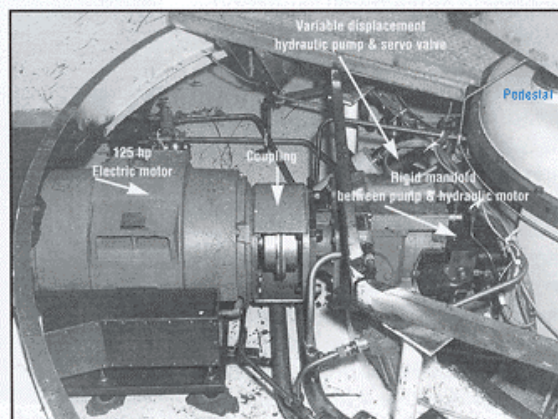


Figure 3. Hydraulic pump and motor drive unit (3 per centrifuge).

pumps and hydraulic motors were rigid manifolds with welded joints (modern American Petroleum Institute codes require the use of flexible connections between these components; switching to flexible hoses would severely impact the performance of these centrifuges). Welded joints are vulnerable to cracks that could be caused by small deflections of the case relative to the motor and pump units. Hydraulic oil under high pressure (in excess of 48 MPa (7,000 psig) during peak onset/decay rates) might be atomized through a small crack, resulting in an oil fog/mist that would burn rapidly and intensely (deflagrate). The design team learned from Sandia-sponsored tests at Fenwal Safety Systems Co. that this particular hydraulic oil, when in the form of a mist and/or fog, would deflagrate at room temperature, producing an overpressure in excess of 689 kPa (100 psig). Also, it was learned from the technical personnel at Fenwal that flame arrestors and/or large vents could not adequately limit overpressure in the event of a deflagration due to the relatively small free volume in the subpit area where the centrifuge drive systems are located.

Safety and performance issues dictate a new design

Although the chance of a oil mist/fog deflagration was small, an ignition source must always be assumed to be present due to motor brush arcing, or many other possible sources of sparks, when these centrifuges are in operation. Sandia decided to investigate designing non-hydraulic replacement drive pedestals for both centrifuges to eliminate this safety hazard. Another design objective would be to eliminate the vibration transmitted to the arm caused by the pistons in the hydraulic motor/pump units and the pinion/bull gear spindle drive system. New drive pedestals and associated electronic control systems would cost more than mod-

ernizing the existing hydraulic systems. However, Sandia believed that eliminating this safety hazard, improving the performance, and long term reliability required it.

Sandia engineers faced a formidable design task. They had to design an electric motor drive system which would produce the same, extremely high, onset/decay rates which were being produced by the very low inertia hydraulic systems at turning rates up to 280 rpm (200 g at the end of a 2.4 m [8 ft] arm). This would require a pulse torque capability greater than 14,900 N·m (11,000 ft·lb), plus that required to compensate for the additional inertia of the electric motor rotor.

Sandia engineers worked with Kollmorgen Inland Motors and Baldor Suedrive to develop the electric motor and controller systems to replace the hydraulic drive systems, and with the Timken Co. for the tapered, double row, roller

bearing spindle support system. It was necessary to preload (-0.001 inch) these bearings for these vertical spindle applications to prevent lower roller skidding in both the upper main bearings and the lower bearings. This required very accurate mounted bearing end play measurements in order to determine the correct spacer thickness for each bearing in both pedestal assemblies. Commerce Grinding Co. performed all of the precision grinding operations associated with these projects, including the large spindles which required plunge ground surfaces up to 76 mm (3 inches) wide for grease seal mating surfaces. The special grease seals were designed, fabricated, and tested to Sandia specifications by JM Clipper Corp.

The motor system design evolved into a brushless, rare-earth-magnet (samarium-cobalt), 72 pole (36 pole pairs) design, with low rotor inertia and a pulse torque capability of 4,100 N·m (3,000 ft·lb)

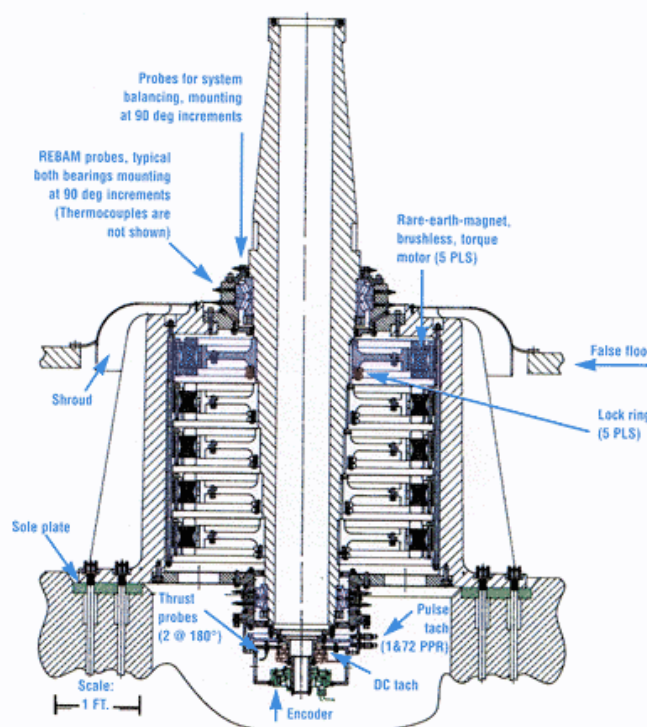


Figure 4. Centrifuge pedestal assembly.

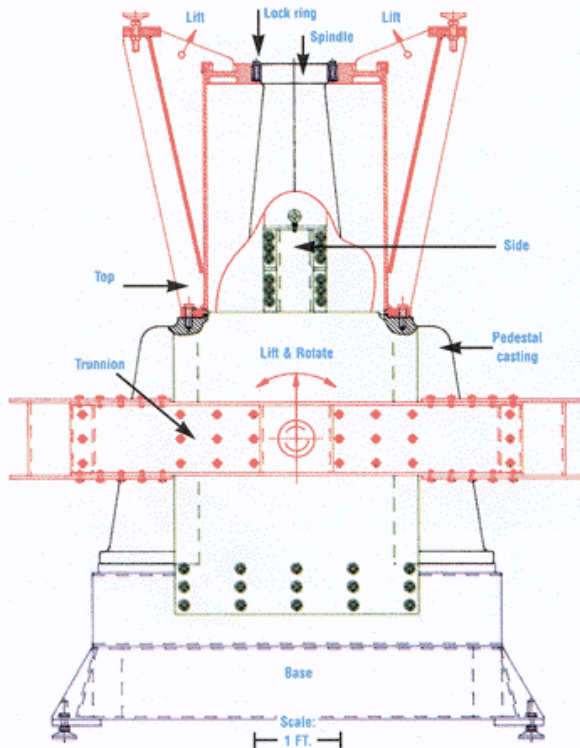


Figure 5. Fixture system for assembling centrifuge pedestals.

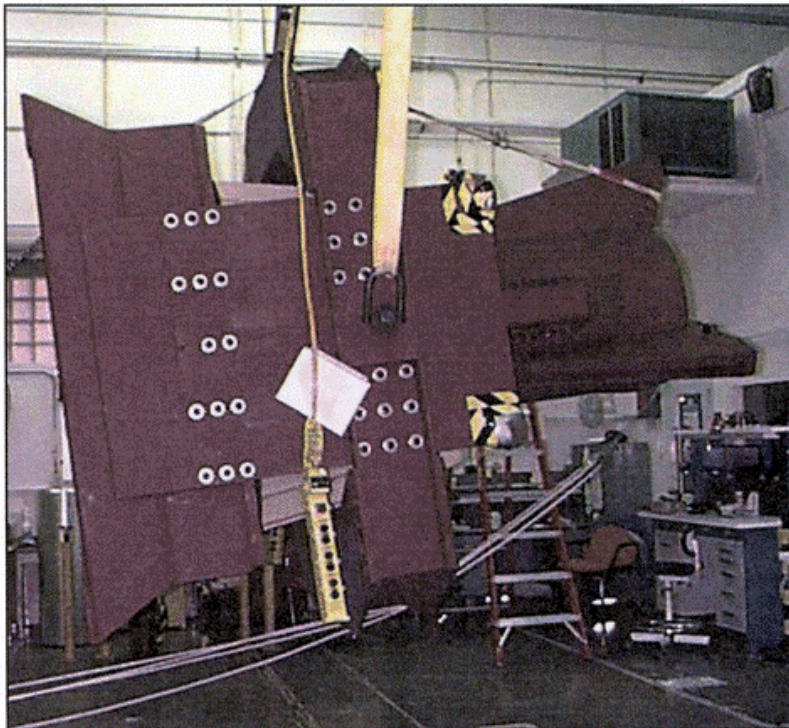


Figure 6. Centrifuge spindle and pedestal casting subassembly being turned upside down.

per motor. Five motors provide a total pulse torque capability of 20,300 N·m (15,000 ft·lb) per pedestal assembly (Figure 4). Each motor rotor is secured to the spindle using special shrink rings designed and built by the RingFeder Co. The motor housing was designed and machined by Sandia from a Meehanite type SP 80 casting, cast by Macaulay Foundry Inc. Sandia designed and built a special fixture so the pedestals could be turned upside down (using 2 overhead cranes and a trunnion system, Figures 5 and 6) to mount the motors, lower bearing and seal subassembly, and lower spindle instrumentation subassembly. Prior to turning the pedestal/spindle/main bearing subassembly upside down, the lower bearing mounting surface on the spindle was accurately centered in the bottom opening of the pedestals using a large lock ring made by Tsubaki Co. (Figure 5). Alignment was facilitated by the use of Bently Nevada proximity probes (these probes were also used during the bearing end play measurements described above) at the top of the spindle, and dial indicators at the bottom of the spindle and pedestal. Particular attention was given to making the top fixture stiff enough to hold the lock ring and spindle centered during motor and lower bearing installation. This prevented movement and possible "poling" of the magnet assemblies due to the very strong magnetic force fields. The poles of the rotating fields (magnet assemblies) and stationary armatures of all 5 motors are held in accurate angular alignment by the use of keyways and pins. Proper alignment is necessary to allow synchronization of all 5 motors per spindle using the signal from a special 8192 pulses per revolution B.E.I. encoder mounted on the end of each spindle. Each motor is driven by a 75 kW (100 hp) controller, and all 5 controllers (Figure 7) operate in unison from a common torque command signal generated

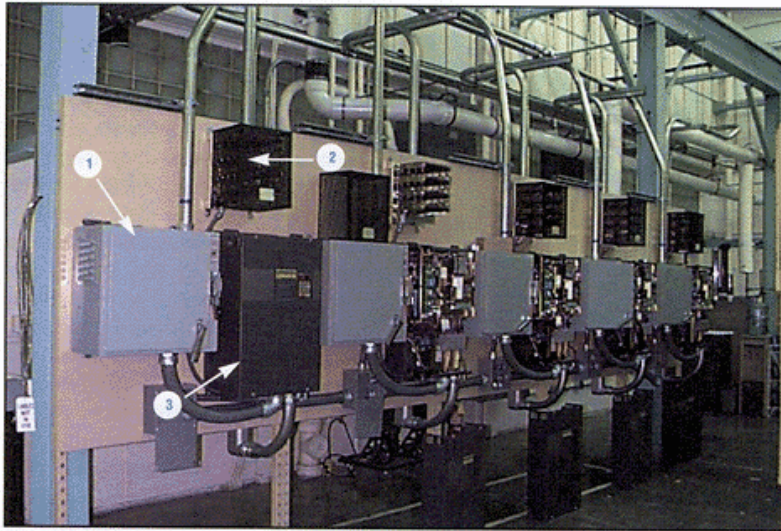


Figure 7. Centrifuge motor controller (5) system: 1) Motor contactor & breaker switch module. 2) Braking resistor module. 3) Motor controller.

from a new, Sandia-designed, centrifuge control console (the consoles for the new centrifuge systems are identical).

Bently Nevada helped Sandia engineers design the monitoring, machinery diagnostics, and balancing systems for the centrifuge upgrade and conversion project. The design included Bently Nevada proximity probes for measuring unbalance response, thrust position,

and bearing state-of-health monitoring. Thermocouples were installed in the windings of each motor and on each bearing (in contact with the outer races). All of the transducers are connected to a Bently Nevada 3300 Monitoring System in the Sandia centrifuge control console (Figure 8). The 3300 Monitoring System consists of a 3300/20 Thrust Monitor, a 3300/54 Dual REBAM Monitor, a 3300/35 Six Channel

Temperature Monitor, and a 3300/61 Dual Vector Monitor. The Dual Vector Monitor, which indicates the vibration amplitude and phase of the centrifuge arm, was specially modified by Bently Nevada for the relatively low speed centrifuge. Also, Sandia has a mobile rack of machinery diagnostic equipment which includes a Bently Nevada ADRE® 2 system, 3300 Monitoring System, and Digital Vector Filter 3; a TEAC data recorder; and a pair of plotters. Once the centrifuge upgrade conversion project is finished, this rack of equipment will reside at WETL for long term trending of these machines and several other special purpose centrifuges. Sandia has used Bently Nevada field transportable equipment for more than 20 years. This equipment has proven to be valuable during the development of many high speed (20,000 rpm) spinners and low speed, precision centrifuges.

The centrifuge's two rolling element bearings are especially critical to low arm vibration operation during weapon component or subsystem testing. For that reason, Sandia engineers designed the bearing housing to accommodate Bently

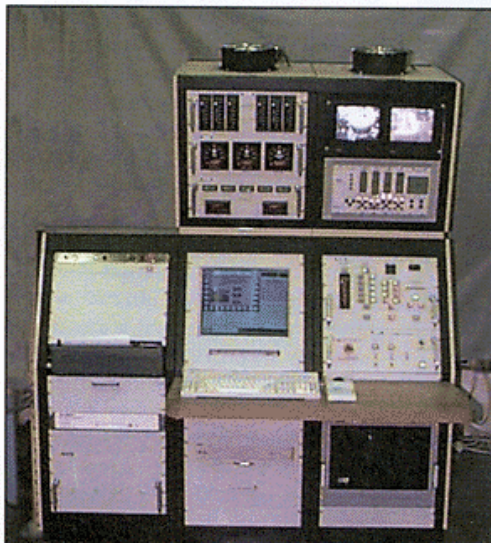


Figure 8. Centrifuge control console with Bently Nevada 3300 Monitoring System.



Figure 9. Core drilling for installing new, 48" long, anchor bolts.



Figure 10. Grouting the precision-levelled sole plate.

Nevada REBAM® (Rolling Element Bearing Activity Monitor) transducers. REBAM transducers are proximity probes that directly observe the outer race of a rolling element bearing, and detect slight deflections caused by the rollers as they pass the outer race probe locations. REBAM probes can be installed at 90 degree increments around each bearing outer race. REBAM probes provide much more information about the condition of rolling element bearings than do case mounted transducers. The REBAM transducer signals are processed in the 3300 rack by a 3300/54 Dual REBAM Monitor.

Sandia and Bently Nevada are jointly designing a special training course for the Operators of these centrifuges. They will learn the proper operation and calibration of the instrumentation for long term machine state-of-health monitoring, and balancing of the various centrifuge arm configurations.

Conclusion

Site preparation and remodeling for the first centrifuge upgrade and

conversion is presently underway at WETL. It was recently learned from Robert Rowan, Jr. (Sandia consultant) of Robt. Rowan & Associates, that the machine anchoring methods used for the old centrifuges do not conform to modern machine anchoring methods. The old anchor bolts (24 bolts per centrifuge) for the first centrifuge replacement pedestal have been removed by core-drilling (Figure 9), new anchor bolts installed, and a sole plate (Sandia furnished) precision leveled, grouted, and installed by M&M Precision Grouting (Figure 10). Upgrade and conversion of the first centrifuge system is scheduled to be completed by approximately October 1997, and qualified for weapon component and subsystem testing by March 1998. At this time, the second centrifuge will be taken off-line for conversion and upgrading.

Sandia's significant design achievement was made possible by the recent advances in the design of rare-earth-magnet, brushless motors and high power and high frequency current switching motor controllers, and the partnership

with key suppliers, such as Bently Nevada.

Bently Nevada Corporation and Sandia National Laboratories have enjoyed a close relationship for more than 20 years. Sandia engineers have used Bently Nevada products and services in a variety of applications. Sandia engineers rely on the accuracy and reliability of Bently Nevada products, which are essential for the precise and critical tests that are performed.

The equipment and facilities at Sandia National Laboratories can be adapted to many different uses. Sandia invites inquiries from other organizations that may need assistance with testing projects. Bently Nevada Corporation is proud that its products and services are chosen by well-respected companies, such as Sandia National Laboratories. ■

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